RECENT ADVANCES IN ASTRONOMY.

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ASTRONOMY is the most ancient among the sciences. Five thousand years ago the builders of the pyramids had considerable accurate knowledge of the starry heavens. Antedating this, possibly, the oriental shepherds and the priestly magi of Babylon knew the first five or six planets and the principal stars and constellations. The patriarch Job mentions Arcturus, Orion, Draco, the Pleiades, and the zodiac. Astronomy was not only the first science mastered, but at the opening of the nineteenth century it was thought to be completed as far as human genius could perfect it, excepting as better instruments should reveal certain details as yet beyond reach. Any intimate knowledge of the constitution, conditions and movements of the stars, so far away that motions from ten to two hundred times as swift as a cannon-ball do not show any perceptible displacement in a century, was thought to be chimerical. Discoveries might be possible in physics, chemistry, biology, geology, etc., but the human intellect had reached its *ultima thule* in astronomy. During the last half of the past century, however, science, which seemed to be hardening into a permanent, finished form, suddenly became plastic again by the injection of marvelous discoveries, and the revolutionary hypotheses founded upon them. In no one of the sciences have greater discoveries or more revolutionary changes been made. Instead of being the most barren field for scientific research, astronomy quickly became one of the most fertile. One cause for satisfaction is the fact that America now leads the world in astronomical equipment and investigation.

The exciting cause for this activity and success in the astronomical field has been the invention and improvement of instruments of research. With all its attachments and improvements, the modern telescope, perhaps, in its mechanical perfection alone, represents the most splendid product of human thought and skill. It is a far cry from the spectacle-lens instrument with which Galileo startled the world to the forty-inch Yerkes refractor, and the sixty-two-inch reflector recently made for the American University, at Washington, D. C. There are now about fifty great telescopes mounted in more or less well-equipped observatories in the United States. There were none until about the middle of the last century, when Professor Mitchell secured and mounted a twelve-inch instrument at Cincinnati,

Ohio. This became the center from which numerous observatories radiated, until now one-fourth of all the great telescopes of the world are in America, and of these by far the most powerful and efficient. Armed with this magnificent equipment, our investigators are outstripping those of other countries. Scores of such men as the two Pickerings, Newcomb, Young, Keeler, Mitchell, Proctor, Barnard, Burnham, Chandler, Gould, Lowell, Ritchey and others have assisted in placing the astronomical bays upon Columbia's brow. We should not forget the Clarkes, Brashear, Swazy, etc.—the Herreschoffs of astronomy.

Hardly a generation ago, Alvan Clarke, of Cambridge, Mass., was possessed with the foolish and presumptuous idea that Europe had no perpetual patent upon telescope-making, and that he, a mere nobody, could grind a lens. Despite the kindly discouragement of the Harvard professor whom he consulted, he ground away until he had perfected a six-inch lens which stood every test that he could apply. He carefully wrapped the precious glass and carried it to the professor's laboratory. Alas for his pride and presumption against the gods of precedent, the lens miserably failed to respond to the very tests he had applied in his workshop! The professor kindly intimated that he had told him so; and, although Clarke had made a really good glass for an amateur, no astronomer would think of mounting it in an observatory. Nearly heart-broken with disappointment, Clarke carried his disgraced lens back home, and again tried the tests, without success. The next morning he tested the lens again, and it stood magnificently every trial the professor had made. It slowly dawned upon Clarke that the lens had been warped by the heat of his body and the strain of transportation. He was more careful the next trip, and the professor forgot his references to amateurs in his admiration of a perfect glass made in America.

Perhaps we have nearly reached the limit of the size and efficiency of refractors, because of the difficulty of polishing large lenses and because of the increased length of the tube required. These difficulties do not obtain, however, with reflectors, and there is no insuperable barrier against the construction of a ten-foot speculum, at least. Such an instrument would cost but a mere fraction of the expense of a battle-ship or an abortive polar expedition, and would extend enormously the range of vision. If there are limits to our stellar universe, and if there are other similar universes beyond, such a telescope might possibly reveal them.

Within recent years the camera has become the efficient handmaiden of the telescope. Photography has indeed worked a revolution in astronomical methods. Heretofore we have had to rely upon

more or less defective drawings to represent astronomical phenomena. What the imagination may depict, let an ancient sketch of a comet, with its hideous train of swords, knives, and bloody heads, attest. The modern astronomer is not so unreliable as that, but an inspection of various drawings of the sun's corona, or the nebula of Orion, will show that the personal equation must be taken into account. The camera, however, is absolutely without prejudice or predilection. Photographs are of inestimable value for future reference in making comparisons to detect possible changes. In addition to this, the photographic plate is more sensitive than the eye, and is able to accumulate the impressions received from hours of exposure, while the eye tires after a few minutes of close observation. The photographic chart of the whole heavens, now being prepared, will accurately locate and give the comparative magnitudes of many millions of stars. The supposed 8000 or 9000 nebulæ, visible with the best telescopes, have been increased twentyfold by a happy experiment of Professor Keeler in photographing without the eyepiece.

The spectroscope, the plaything of the physicist a half-century ago, has become the magic wand of the astronomer. With it he analyzes the constituents of stars away out on the fringe of the universe, so distant that fleet-footed light takes hundreds and even thousands of years to traverse the vast gulf, and he does it as easily and accurately as if they were on his laboratory table. The unseen atmospheres and the physical conditions of these bodies are also revealed. In this way the wondrous unity and identity of the universe have been established, perhaps the greatest single feat of modern astronomy. Many of these stars are shown to be unfinished suns, whose vast bulks are due to the uncondensed nebulæ or "fire-mist" or meteoric matter of which they are composed. Giant Arcturus, for instance, has been estimated to be a million times the size of our sun. If this estimate is correct, and the earth were represented by a sand grain, and the Omnipotent should pour out of His mighty hand ten such world sand grains per second, it would take over 4000 years for enough earths to trickle out to make one Arcturus!

A few stars had been suspected of having dark companions or satellites revolving around them even before the advent of the spectroscope, but this instrument has definitely shown that a considerable fraction of the stars have such planetary bodies of notable size circling about them, thus completing the analogy with our own solar system. By implication, most if not all of the hundreds of millions of such luminaries are attended by such invisible satellites. This revelation of unseen worlds is little short of miraculous. The human conception fails to grasp the magnitude of such a starry universe.

Hundreds of other stars are spectroscopic doubles, as shown by the periodic doubling of their lines. These may be embryo solar systems. The periods of these are so short as to suggest this. The theory of the younger Darwin, that tidal waves of the nebulous and molten matter, in the new-made world, and the aqueous surface of cooler bodies, regulate the distances and periods of stellar companions. These tides retard the rotation and increase the velocity of revolution until a balance is established between the tangential and gravitational forces. According to this theory, planets and other satellites began their career with much less periods and shorter distance from their centers of revolution than they now occupy. A short period, therefore, probably indicates a new-born world, and a large orbit and long period, maturity.

It has long been known that many stars have a proper motion at right angles to the line of vision. Motion directly toward or away from the solar system was thought to be beyond our ken. The spectroscope, however, shows in a moment of time whether the star is approaching or receding from us, and even the rate can be accurately computed from the displacement of its lines in the spectroscope. Nearly all, if not entirely all, so-called "fixed stars" are shown to be in rapid motion, varying from 10 to 300 times as swift as a projectile from a modern gun; 1830 Goombridge and 243 Cordalea, sometimes called "the runaway stars," have such trememendous velocities that the gravitation of the stellar universe is not sufficient to account for them. Possibly these are stellar missiles swiftly traversing our universe from the infinite depths beyond.

Our own sun is found to be moving like its neighbor stars. It is drifting at a rate of from twelve to sixteen miles per second toward a point some thirty degrees from the pole of the ecliptic. The earth and other planets are thus tracing out mighty spiral courses through the universe, never returning to the same point again, unless the sun's motion be an orbital one. If this is true, the curve is probably around the common center of the galaxy, or possibly a spiral one due to the common form of nebulæ. One investigator says the concept of this swift but silent flight of the sun, with his attendant planets, is the most overwhelming thought the human mind can grasp.

We should not leave out of our category of telescopic aids the chronograph and the bolometer and radiometer. The two latter instruments are inventions of Americans, and are invaluable in measuring the heat radiations of the stars, the moon (over its dark surface), and planets. These instruments are so delicate as to give accurate data, after making due allowance for absorption from the atmosphere. They are said to be able to detect and measure the radiations of a candle several miles distant, or of even a human face a mile away.

Taking a hasty survey of some of the accomplishments of the past forty years, we note that the earth has been more accurately measured and weighed. The sun, which was supposed during the early part of the last century to be inhabited, and even the abode of the blessed, according to one philosopher, is definitely demonstrated not to be a fit heaven, however much it may fill the requirements of "the other place." All our electric and magnetic storms are probably traceable to solar disturbances. Serious efforts are also being made to found weather prognostications upon well-known cycles of solar conditions.

The moon, our nearest neighbor, or only child, as you choose, has been awakened out of a supposed sleep of death by Professor Pickering. We have been teaching with parrot-like volubility and assurance that the moon is a dead world, without a trace of atmosphere or water in either liquid or gaseous form, and that, as a consequence, it was a rugged, barren waste, utterly devoid of any life whatsoever. The above conditions were definitely proven by occulted stars shining with undimmed splendor until blotted out by the moon's disk. This was yesterday. Professor Pickering says that an occulted star *is* dimmed upon approach to the moon, as any close observer can see. He thinks that there is unquestionably a rare atmosphere, and he believes that certain changes in hues about and within certain craters are due to a low form of vegetable life, perhaps like our fungi. The brilliant white spots, so prominent a feature of lunography, Mr. Pickering thinks are due to snow. The average astronomer dislikes to be caught napping, but when Professor Pickering speaks the astronomical world listens and takes notes. He has had unusual opportunity to verify his observations and strengthen his conclusions under the most favorable conditions.

Mercury and Venus still hide their mysteries of topography under a thick veil of dense atmosphere. It is still uncertain whether they rotate faster than the period of their revolution or not. Upon the answer to this question hangs the possibility of their being inhabited. It is probable, however, they are dead worlds which always present the same face to the sun. Mars continues the observed of all observers, because of the wealth of detail visible under favorable conditions. The war of theories as to the nature and meaning of the so-called canals is still being waged. Some insist they are mere optical illusions, and cite traces of similar appearances upon other planets and the moon, and the fact that some of them enter or cross the supposed seas. Others as stoutly assert they are not only real entities, but are water-courses or possibly lines of vegetation accompanying such irrigation ditches. This latter view is supported by Mr. Lowell, who has closely observed the planet at the observatory at

Flagstaff, Ariz. This much seems reasonably certain: there is a polar cap of snow that waxes and wanes with the round of seasons, and these canals and seas increase with the melting of this snowy mantle. What are thought to be clouds have been observed in the Martian atmosphere, and some claim to have seen the actual deposition of snow from these clouds. Mars is undoubtedly the most like our earth of any of the easily observed planets, and very probably furnishes suitable conditions for some kind of life. Professor Hall, of Washington, D. C., made the remarkable discovery of the two tiny satellites, which Swift, in "Gulliver," so wonderfully predicted, as to size and distance. This feat of astronomical detective work is said to be as difficult as the recognition of a tennis-ball at the distance separating Boston and New York.

The curious little planetoids have been multiplied until they number about 500, and the discovery of a new one is treated with indifference, unless, like one of the last, Eros by name, it presents some anomaly of position or motion. The plane of this planetoid's orbit makes an unusually large angle with the ecliptic, and it passes in one part of its path within the orbit of Mars, thus becoming our nearest visitor, excepting the moon. Concerning the outer planets, not much has been added within recent years. Barnard signalized the excellence of the Lick telescope by ferreting out the fifth satellite of Jupiter; and one of the Pickerings has found the ninth satellite of Saturn, naming it Phœbe. Professor Keeler, who succeeded Barnard definitely proved by the spectroscope that the rings of Saturn are neither solid nor liquid, but meteoric in form. These rings are practically annular masses of tiny satellites circling about the planet. They are supposed by some to be moons in process of formation. If so, we are witnessing the manufacture of worlds in God's workshop. This was thought at one time to be the normal form assumed by the primal nebulæ in all cases of world-formation, but, as we shall note later on, it is probably an anomalous condition. Saturn itself is still in embryonic state, as shown by its low specific gravity, and the other major planets are in the infant stage of development. The famous red spot of Jupiter has greatly diminished in size and brilliancy.

During the early half of the nineteenth century it was gravely suggested that the cometary visitors to our system were "excursion trains" for the especial delectation of those astronomers who had "come up through great tribulation," and who wished to inspect the stellar universe at closer range. These supposed trains, with their gala-day banners, went whisking now through this and then that solar system. These excursion trains, through good telescopes and in the spectroscope, look strangely like the other commonly distributed nebulous

masses. The relation of comets to meteoric showers has been established within recent years.

The radiometer and spectroscope have given us valuable data regarding the condition and stages of the so-called fixed stars. There are at least three well-defined classes—those of the Sirian, the solar and the *a Herculis* types. The first are whitish stars, whose spectra are marked by bright lines, the dark lines indicating hydrogen, or by the violet and ultraviolet colors. This represents an early stage of stellar development, some indeed seeming to be mere aggregations of nebulous matter. Those of the solar type have spectra rich in dark lines of many elements, and represent a maturer condition. Those of the last type indicate rapidly cooling suns, and are marked by reddish or other pronounced spectral tints. There has not been much advance made along the line of measurement of distances, the parallaxes of hardly a hundred stars being definitely determined. Enough has been accomplished, however, to give us the general distances and to show that there is no definite relation between size and proper movements and distance.

The temporary stars that occasionally flash out brilliantly and then die down to invisibility have long been subjects of interest and speculation. During the fall of 1899 a new star appeared in Perseus and rapidly grew in brightness until it reached the first magnitude. It then faded away, but, luckily for the interests of science, has been followed assiduously and its various changes carefully recorded and photographed. Nova Persei was thus found to have developed into a rapidly swelling nebulous mass whose swift centrifugal motion resembled, and even surpassed that of an explosion. It is believed that it arose from the collision of two so-called dark stars whose impact not only shattered them, but transformed them into lambent gases. It is believed by many that this nebulous mass will in time cease its expansion, and then begin to condense under the effect of gravity, giving rise to a new stellar system, under the working of the laws of the modified nebular hypothesis. Perhaps this may represent one stage in an endless cycle of stellar evolution, which normally includes collision, nebulous mass, rotating spiral, a central mass with various attendant satellites, and finally a darkened star. This at least is believed by many notable investigators.

Until within the latter half of the past century, the nebulous masses revealed here and there were considered star clusters, too far away for our telescopes to resolve into their constituent stars. The spectroscope, however, proves most of the persistent nebulous masses to be really gaseous and meteoric in form. They are probably the world-stuff from which suns and planets are made. This is somethin

more than hypothetical, since many constellations, such as Orion, still have wisps of nebulæ trailing after the principal stars, as if they were not yet the finished products of creative efforts. Most of the well-known constellations, too, show other evidences of close relationship —common spectral lines and similar proper motion. Most of the star clusters have unresolved nebulous masses within them. The six bright stars lying in an empty space in the heart of the great nebula of Orion, like diamond eggs in a world-nest, strongly suggest their origin from that nebula. Recent photographs show that the normal shape of nebulous masses is spiral, as if under the influence of tangential and gravitational forces. This may lead to a modification of La Place's hypothesis, whereby attendant stars and planets arise from masses switched off from such rotating nebulæ, instead of collecting first in the form of rings like those of Saturn. If this be true, this planet and such annular nebulæ as that in Lyra are anomalies. It is suspected also that the galaxy conforms to the prevailing spiral type. Some nebulæ show but very few spectral lines, as if made up of those elements only. If there is an identity in structure and nature throughout the universe, all the elements, or most of them, ought to show in the spectrum. This has given rise to the theory that these masses are truly embryonic, most of the elements being as yet undifferentiated. Professor Haeckel believes that matter arises from condensations of ether, hydrogen being the simplest sensible matter, or perhaps a hypothetical substance he calls prothyl. From differentiations of this all the other elements arise. Other astronomers think that the reason only two or three elements appear in the spectrum is that the lightest gases are thrown out to the periphery of the masses by whatever forces generated the nebulæ, but that after a time these settle so as to reveal the heavier substances. In any case, we are witnessing the processes of world-formation in nebulæ.

Perhaps you will pardon, in closing, the mention of a curious hypothesis proposed by Wallace, the codiscoverer with Darwin of evolution. He believes that the earth is the only inhabited world in the universe, citing as proofs the almost central position of the sun in the galaxy, and the peculiar balance of gravitational and other forces thus arising, and from the particular position of our planet in the solar system. There can be no doubt that the position of the earth is unique, and must necessarily be, because of the principle that two bodies cannot occupy the same space at the same time. It is also incapable of proof that any other member of the solar system is inhabited, as it is equally impossible to prove the negative. The argument of peculiar position and delicate balance of forces, however, seems comparable to the reasons that a shark inhabiting the Caribbean sea

might advance that "the multitudinous seas" outside his especial preserve must necessarily be uninhabited, because that sea occupies a peculiarly central position with respect to the American continents and the Atlantic and Pacific oceans, and because its temperature, depth and degree of saltness must be different from other parts of the earth's water surface. This theory has been argued *pro* and *con*, however, although it must be admitted that astronomers are decidedly *con*. Nikola Tesla has made himself the target of humor by asserting his belief that he had received "Teslagrams," so to speak, from the inhabitants of Venus and Mars.

To summarize even this brief survey of the advances astronomy has made within recent years is to mention most of what is taught in modern text-books. In other words, astronomy, in common with other sciences, has been revolutionized with the past fifty years. The doors to original research and discovery, heretofore almost closed, have been flung wide open, and invite to most fruitful fields of investigation. Armed with the most perfect instruments ever devised by human ingenuity, and supported by an interminable line of wonderful discoveries, nothing seems impossible to the astronomer.

The poet has voiced not only the expectation of the unscientific, but of the astronomer himself in his address to the telescope:

> "Through thee will holy Science, putting off
> Earth's dusty sandals from her radiant feet,
> Survey God's beauteous firmament unrolled
> Like to a book new-writ in golden words,
> And turning the azure scroll with reverent hand,
> Read to man the wonders God hath wrought."